

National Aeronautics and
Space Administration



marshall

POCKET**GUIDE** 2015

*Launching the Future of
Science and Exploration*



Launching the Future of Science and Exploration

Fiery rockets
 bound to discover the
 unknown. Men and women
 doing research every day aboard a
 giant orbiting laboratory. Telescopes and
 probes staring into the distant depths of
 the universe and the wonders of our own
 changing planet. Behind all these incredible
 accomplishments you will find the
 vision and expertise of the teams
 at NASA's Marshall Space
 Flight Center.

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NASA's Strategic Direction

NASA Mission

Drive advances in science, technology and exploration to enhance knowledge, education, innovation, economic vitality and stewardship of the Earth.

Exploration Plans

We are at the threshold of an unprecedented era in space exploration. NASA's bold vision for the future is to expand human presence throughout the solar system. The ultimate aim: men and women walking on the red sands of Mars.

With the International Space Station (ISS) as a testbed and the collective efforts of many nations, NASA envisions the following accomplishments are possible over the next 25 years:

- A deep space habitat is deployed to an Earth-moon Lagrange point.
- Robotic missions provide greater knowledge of the worlds we plan to visit.
- Humans visit a near-Earth asteroid.
- Humans return to the moon for longer stays and possible habitat development.

Each step is a remarkable achievement in its own right. And each step fosters development of new capabilities, technologies and systems to place humans on Mars. Marshall's diverse and talented team, with proven technical and scientific know-how and state-of-the-art facilities, plays key roles at every step.

Why Explore

Early in our lives an innate thirst for knowledge sets us stargazing in delicious anticipation of what we might see. Space exploration both quenches and perpetuates that thirst through a never-ending wave of discovery, creating a better future for humankind by

- Expanding the frontiers of scientific research.
- Enhancing our knowledge of planet Earth and the measures needed to protect it.
- Driving innovations and advancements that improve and even save human lives.
- Invigorating the country's economy by sparking technology advancements and creating new industries.
- Encouraging international cooperation.
- Inspiring new generations of engineers, scientists and technologists.

Join us as we unlock the mysteries of space and harvest its limitless benefits for humankind.

We've really only just begun. Look up. That's where we're going!

About Marshall

Adaptable, affordable, inspiring



From the development of mighty rocket engines to extraordinary scientific discoveries about our universe, Marshall Space Flight Center is launching the future of science and exploration.

Marshall brings vital resources to NASA and the nation for solving the unique challenges of space exploration. Our capabilities and experience are essential to nearly every facet of NASA's mission of exploration and discovery as we:

- Develop and test tomorrow's flagship space vehicles and rocket engines.
- Create new ways to support living and working in space.
- Observe Earth to better care for it and ourselves, and explore the solar system and beyond to increase our understanding of the cosmos and our place in it.

Marshall Goals

- Develop and operate integrated vehicles and systems to enable human space activities.
- Develop, integrate and operate instruments and conduct research to expand knowledge of the universe.
- Develop, test and mature new space technologies to enable NASA missions and benefit the nation.
- Provide and manage program, project and institutional capabilities to conduct NASA and Marshall's space activities.
- Share NASA and Marshall with the public, educators and students to foster communication, participation and innovation to benefit the interests of the nation.

Marshall Profile

- **Over 6,000** employees (civil service and contract, including Michoud Assembly Facility in New Orleans)
- **3rd largest employer** in the Huntsville area
- **More than 125** unique and specialized facilities and labs
- **26 core capabilities** including key facilities and expertise
- **\$2.4 billion** FY 2015 budget



Sustainability

Marshall is decreasing utility, operations and maintenance costs to create a leaner, greener campus by replacing inefficient buildings with LEED-certified (Leadership in Energy and Environmental Design) buildings. Marshall now has seven such buildings with more under construction.

Marshall in the Community

Marshall is located in Huntsville, Alabama, on the U.S. Army's Redstone Arsenal. The Arsenal is a major federal research, development, test and engineering center for the nation's missile defense and aviation programs.



The adjacent Cummings Research Park is home to 300 defense, aerospace and technology corporations and The University of Alabama in Huntsville, with one of the highest-rated engineering management programs in the nation.

Huntsville's unique synergy of government, business and university research creates a fertile environment for collaborating with other agencies, commercial

companies and academia. We are engaged in more than 200 partnerships, fostering co-development of technologies or providing NASA capabilities to the private sector and academia. Such teamwork is essential to developing innovative technologies for future space missions. These partnerships not only make space flight more affordable, they also contribute to our nation's economic strength as these innovations transfer to commercial use.



Education and Outreach

NASA has a long-standing tradition of investing in the nation's education programs. Education plays a central role in preparing, inspiring, exciting, encouraging and nurturing today's young minds—the workforce of tomorrow.

Marshall hosts several efforts to foster education in Science, Technology, Engineering, and Mathematics (STEM):

- The **NASA Human Exploration Rover Challenge**, formerly known as the Great Moonbuggy Race, is an engineering design challenge that focuses on NASA's future mission planning and crewed space missions to other worlds. Participants design, construct and test technologies for mobility devices to perform in different extraterrestrial terrain environments.
- **Student Launch** is a research-based, competitive and experiential exploration project that provides relevant and cost-effective research and development to support the Space Launch System. The project involves reaching a broad audience of colleges and universities across the nation in an eight-month commitment to design, build and fly payloads or vehicle components that support SLS.
- The **One Stop Shopping Initiative (OSSI)** enables eligible students to access student opportunities through a single portal (<http://intern.nasa.gov>) and single application, allowing students to search and apply for all types of higher education internship, fellowship and scholarship opportunities.
- The Marshall **Educator Resource Center (ERC)**, located at the U.S. Space & Rocket Center, provides resources, expertise and facilities for formal and informal educators. NASA's unique mission provides rich content for educational products aligned with national STEM standards.



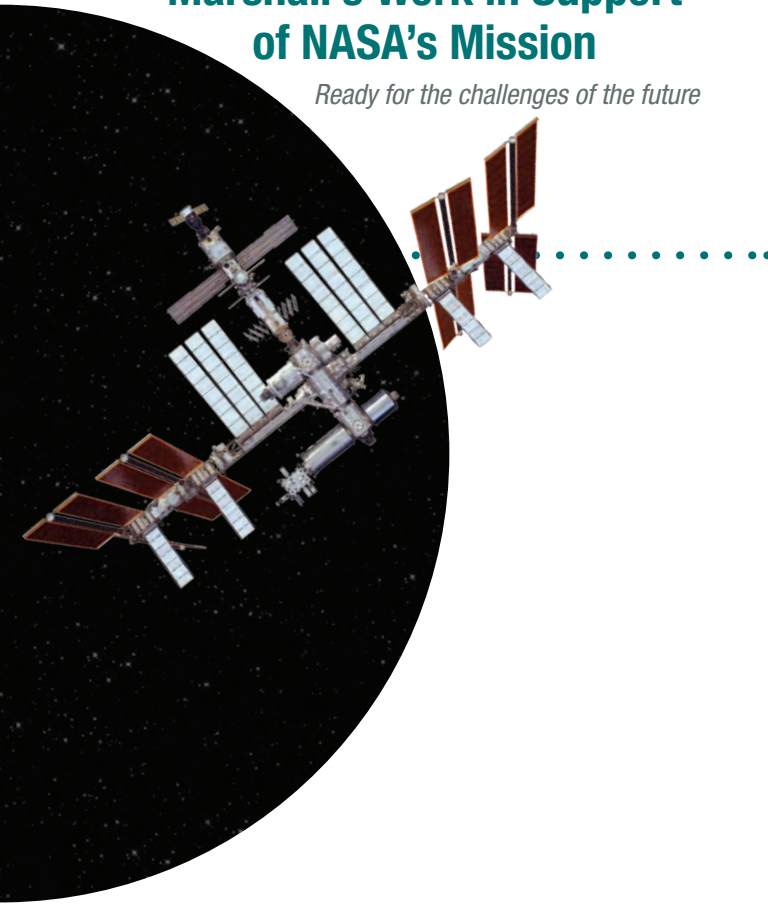
Learn more

About Marshall

<http://www.nasa.gov/centers/marshall/overview.html>

Marshall's Work in Support of NASA's Mission

Ready for the challenges of the future



Marshall supports the Agency's efforts in

- Traveling To and Through Space
- Living and Working in Space
- Understanding Our World and Beyond

The Marshall team is leading development of NASA's Space Launch System, or SLS. The new heavy-lift launch vehicle will send human explorers, their equipment, cargo and science payloads on new missions of discovery beyond low-Earth orbit and provide backup transportation to the International Space Station.

Marshall is also developing advanced, affordable space systems and technologies that enable astronauts to live and work safely in the harsh space environment—whether in the space station's active research facilities or during long-term, deep-space expeditions.

And we are developing robust science missions to expand understanding of our planet, the solar system and the universe.

All of these activities support high-value research and discovery missions in deep space, strengthening our nation's technology base and economy and inspiring the world.



Traveling To and Through Space

Lifting From Earth

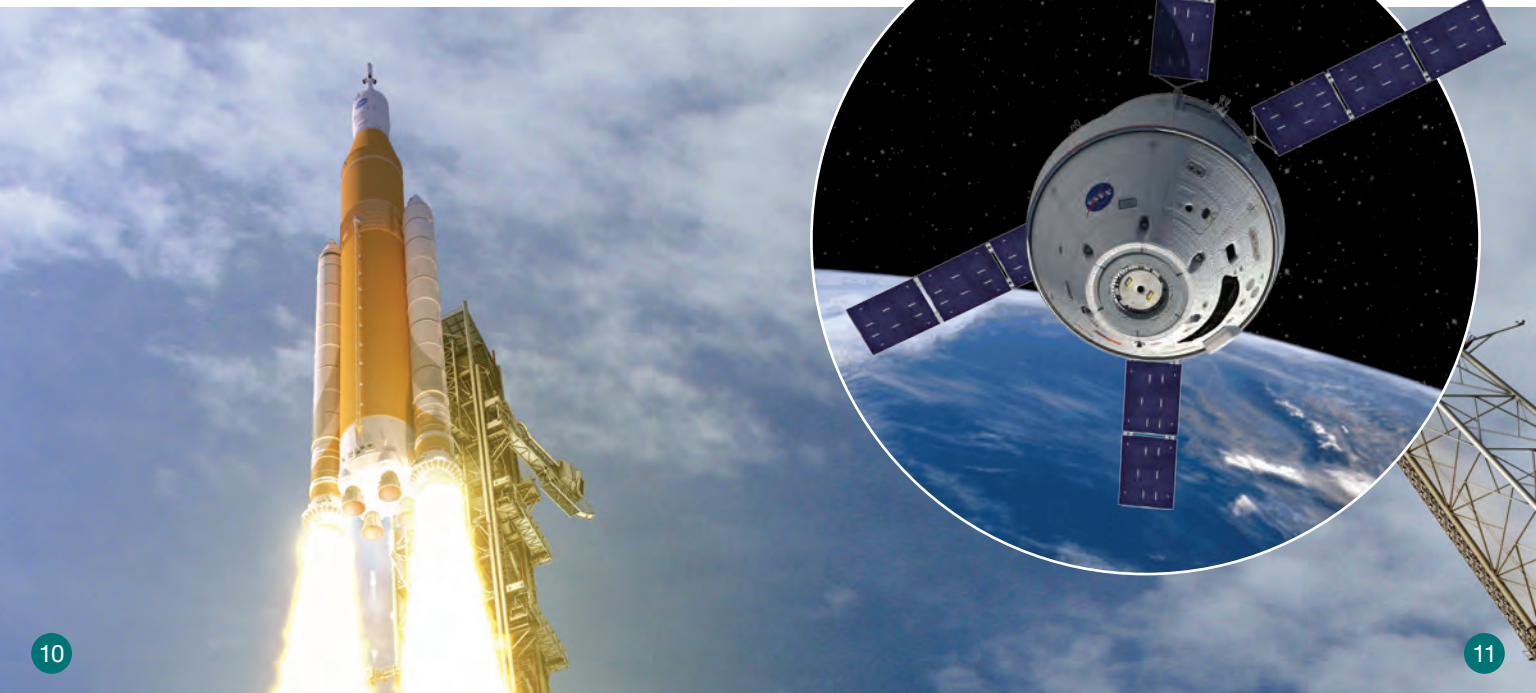
The nation's journey to space began at Marshall more than a half-century ago. And now our dedicated team is guiding the development and testing of tomorrow's flagship rocket, systems and engines. Marshall has been at the forefront of the country's space propulsion and transportation achievements since the beginning of the space race. We are merging lessons learned from past programs with the best practices of today's industries to provide solutions for the new challenges of the 21st century and beyond.

Space Launch System

A key capability in NASA's Journey to Mars is the Space Launch System (SLS), a new exploration-class rocket with the power to loft the massive systems needed for human landings on the Red Planet. Marshall is managing development and construction of SLS, which will be the most powerful rocket ever built and will enable not only human exploration of deep space but also game-changing robotic science and other missions of national importance.

Benefiting from Marshall's long history, experience and insight into propulsion and vehicle development, including the Saturn V and the Space Shuttle, SLS will form the foundation, along with the Orion crew vehicle, for safe and sustainable human exploration, expanding America's presence in space and contributing to economic growth.

Components of the SLS vehicle are being built across the nation. Marshall is performing SLS systems engineering and integration, bringing together the exacting work of American companies in 45 states. The upgraded solid rocket boosters for SLS are being tested in Utah, and testing of the RS-25 core stage engines is underway at Stennis Space Center in Mississippi. At the Michoud Assembly Facility in New Orleans, some of the world's largest and most advanced space vehicle manufacturing tools have already produced the first flight hardware for the SLS core stage. The SLS Program saw its first hardware fly as part of the Exploration Flight Test of Orion in December 2014.



The first SLS vehicle, which NASA has committed to have ready for launch in 2018, will be able to launch more than 70 metric tons of payload to low Earth orbit, approximately three times the capability of the Space Shuttle. The rocket will be upgraded with a new upper stage and later with advanced boosters, ultimately increasing its performance to be able to launch more than 130 metric tons to Earth orbit, greater even than the Saturn V rocket that launched human missions to the moon during the Apollo program.

Offering unparalleled mass lift capability, payload volume and Earth-departure energy, SLS will make possible new payloads and mission profiles that cannot be flown with today's rockets, from speeding science spacecraft through the outer solar system years faster than would otherwise be possible to launching habitats that will help keep astronauts safe and healthy for long durations in deep space.

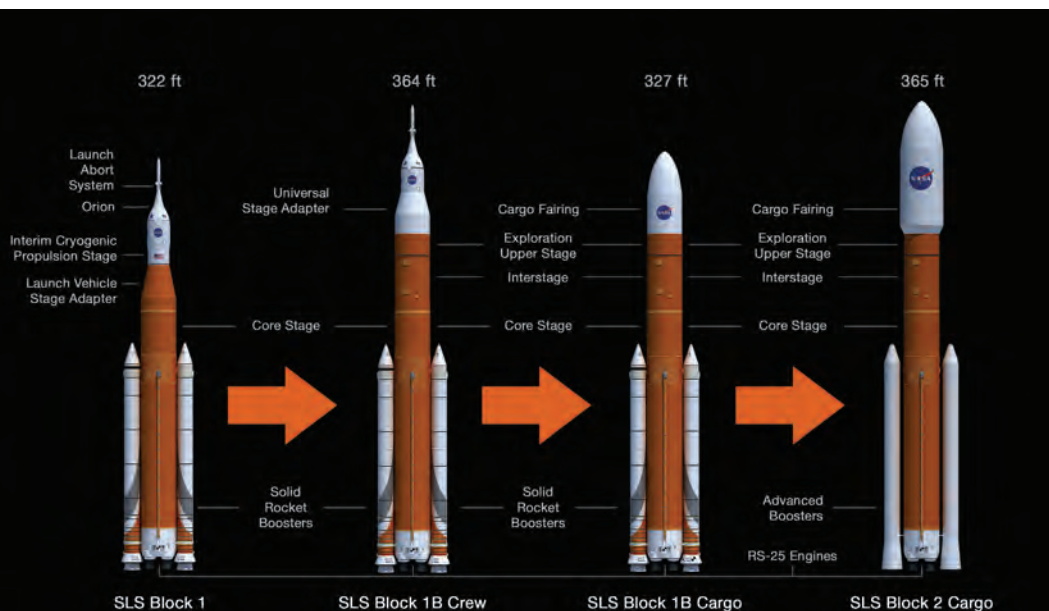
The first flight of SLS will launch Orion beyond the moon, which will be the first time a vehicle designed for humans has journeyed to deep space in more than 40 years. During this flight, tucked inside the ring connecting Orion to SLS will be multiple self-contained satellites each about the size of a large shoebox. This will make it

possible for groups that otherwise might not be able to afford a dedicated rocket launch to fly innovative ideas that can help pave the way for exploration.

The second flight will carry American astronauts farther into space than anyone has ever gone. To ensure astronaut safety, Orion is equipped with a Launch Abort System (LAS) that can activate within milliseconds if a problem arises during launch, pulling the spacecraft to safety and positioning the crew module for a safe landing. Marshall played a key role in developing the LAS by maintaining propulsion oversight and led responsibilities for safety and mission assurance as well as fabrication materials and processing.

After the second flight, SLS and Orion will undertake increasingly ambitious missions into the "Proving Ground" of space near and beyond the moon, testing out new systems and capabilities we will need to venture farther. Marshall is already hard at work developing key technologies focused toward enabling our push toward the Red Planet.

The Journey to Mars is underway.



Learn more
www.nasa.gov/sls

Mars: Join Us on The Journey.
#JourneytoMars

Supporting Commercial Spaceflight

Marshall plays a vital role in enabling and enriching the commercial use and exploration of space. Together, Marshall and industry are helping to prepare the nation for the challenges of a future unfolding far beyond the boundaries of our home world.



Photo credit: United Launch Alliance

At Marshall, we offer our laboratories, test sites and other cutting-edge facilities—plus the expertise of our scientists, engineers and propulsion experts—to leading aerospace companies and small businesses. The center maintains more than 300 active Space Act Agreements and other partnerships with leaders in industry and government. Our goal is to foster development of innovative commercial resources, capabilities and spinoff technologies that benefit everyone.

These partnerships often help improve our own processes and products as we learn of commercial companies' innovative management practices and cost-effective solutions.



Propulsion Systems Research

At Marshall, we are developing safe, affordable, cutting-edge propulsion systems and technologies to enable human and robotic excursions to points all across the solar system.

The center is NASA's primary resource for design and development of space propulsion systems. We build on the engineering expertise that launched a half-century's worth of famous space transportation and propulsion systems—from the Apollo-era Saturn moon rockets, to more than 130 space shuttle flights and a host of robotic science missions.

The temperatures, pressures and other extreme environments associated with liquid and solid rocket propulsion push the limits of engineering. Marshall has decades of experience in design, analysis and testing of everything from coatings and other materials to rocket nozzles and other structures and complete systems such as turbopumps. We also investigate bold new alternative propulsion systems, such as "green" propellant and in-space propulsion systems. These include a range of innovations, from solar sails to nuclear-based technologies that could revolutionize future robotic and human exploration across the solar system.

National Institute for Rocket Propulsion Systems

The mission of the National Institute for Rocket Propulsion Systems (NIRPS) is to foster a vibrant rocket propulsion community that provides reliable and affordable propulsion systems for the nation's defense, civil and commercial needs.

Rocket and missile propulsion systems are critical to national security, space exploration, economic growth and education. Recent studies have warned that the supporting propulsion industrial base is eroding due to long-term industry downsizing, a shortage of new programs, limited career opportunities and rising pressure on discretionary federal budgets.

The goal is to collaborate with all sectors of the U.S. propulsion base to develop policy options and identify technology needs and required guidance. Bringing together stakeholders in government, industry and academia, NIRPS offers strategies to integrate and maximize available national resources to meet future demand.

Recent accomplishments between NASA and the Department of Defense include the utilization of the Joint Army Navy NASA Air Force (JANNAF) collaboration to establish the Programmatic and Industrial Base committee, the development of an industrial base assessment tool and addressing cross-agency procurement plans for critical propulsion elements and materials. Through NIRPS, Marshall provides technical and administrative contract support to JANNAF while also supporting NASA's propulsion activities and the nation's propulsion industrial base.



Living and Working in Space

Marshall creates the systems humans need to thrive in space and supports operations for scientific research in that challenging environment.

As NASA prepares for human exploration of the solar system, center teams are researching and developing methods to protect humans and equipment from space weather and radiation. Building on expertise gained in developing the life support systems for the International Space Station (ISS), we are also working on systems to sustain crews during long-duration missions.

In addition, Marshall scientists, engineers and technologists develop systems that support science operations and investigations on the ISS. The station remains an important vantage point for studying Earth and space and unites many nations through science and exploration. Our Payload Operations Center (POC) coordinates science operations on the station. This responsibility is pivotal to America's leadership role in the station's global partnership and builds collaboration that will be fundamental to future space ventures.

Learn more

<http://nirps.msfc.nasa.gov>

NIRPS

National Institute for
Rocket Propulsion Systems

International Space Station

ISS has successfully demonstrated the convergence of science, technology and human innovation that is not possible on Earth. Marshall led the design, development and testing of the space station's **Regenerative Environmental Control and Life Support System (ECLSS)**. ECLSS “breathes life” into the station, providing water and oxygen for crew members and recycling waste water into usable water.



Engineers and scientists at Marshall also led development of four key systems supporting science operations and investigations aboard the station:

- Eight **EXPRESS Racks** house a variety of science experiments, supplying them with power, data and video distribution and thermal control interfaces.
- The **Materials Science Research Rack** allows crew members to perform materials research in microgravity, leading to the discovery of new or improved materials.
- The **Microgravity Science Glovebox** provides a sealed environment for astronauts to conduct experiments containing potentially hazardous fluids, flames, fumes or biologicals.
- The **Window Observational Research Facility**, or **WORF**, is the station’s “window on the world,” enabling Earth imaging via cameras, multispectral scanners and other specialized equipment.

The ISS is proving to be an amazingly flexible laboratory and invaluable technology testbed for a range of potential solutions to the challenges of human space exploration.

International Space Station

We're Working Off the Earth, For the Earth.
#ISS

Payload Operations Center (POC)

The POC at Marshall is the 24/7 command post for research and technology activities aboard the space station. The POC manages all U.S. science experiments, coordinates with the international partners and trains astronauts and ground team flight controllers. With a focus on increased utilization, Marshall provides strategic and tactical leadership for scientific payload operations.



The POC controls science operations remotely, receives vital information from the station through telemetry signals and monitors research operations using downlinked video. This facility is also a certified backup control center for the station and can support space station command and control if Johnson Space Center flight controllers must relocate here due to a hurricane or other emergency.

As the heart of space station science operations, the POC is fundamental to pushing the boundaries of our country's scientific frontiers.



Learn more

International Space Station Research & Technology
www.nasa.gov/mission_pages/station/research/index.html

Payload Operations Center
www.nasa.gov/centers/marshall/earthorbit/ops.html

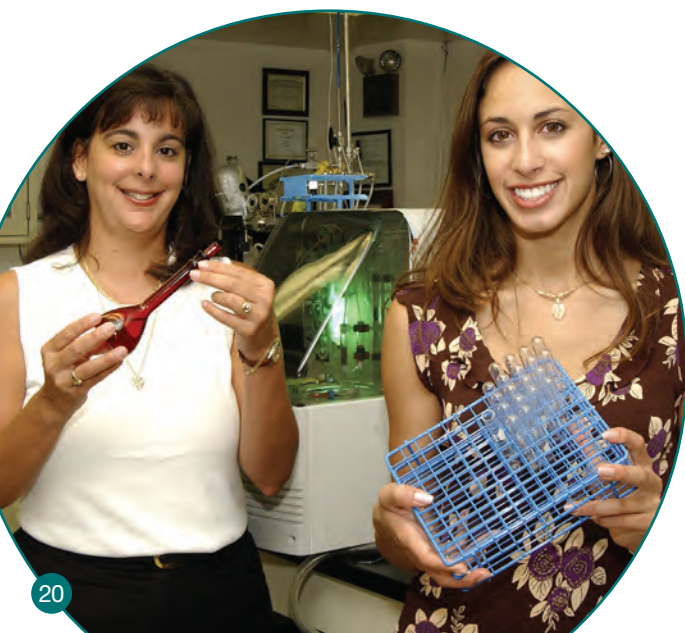
Future Systems

Whether working in the space station, traveling across the solar system or exploring the surface of a new world, humans will require innovations in systems and technologies.



Advancements in hardware and systems for generating and recycling life-sustaining resources will become increasingly important. Our researchers are developing new and better ways to recycle air and maintain clean, healthy living spaces in the space station and in vehicles headed for deep space.

Marshall teams also develop materials, products, tools and technologies to mitigate the harmful effects of space weather and radiation on human and robotic explorers and their vehicles, science payloads and supplies. Our research and development efforts include planetary habitats and structures, dust management methods and debris shielding.



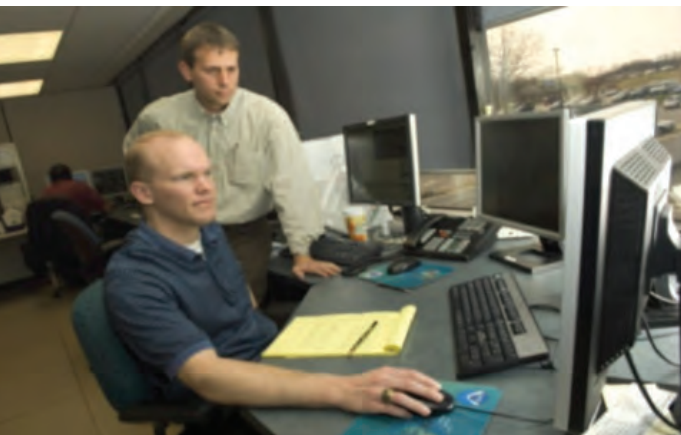
Understanding Our World and Beyond

Whether studying what's happening on Earth today or investigating phenomena at the edge of time itself, Marshall thrives on a strong synergy between science and exploration. Center teams use specialized scientific spacecraft and instruments and innovative research and monitoring techniques to explore our own planet and the worlds within and outside our solar system.

Marshall was instrumental in managing the design, development and construction of the Hubble Space Telescope. For more than 25 years, Hubble has helped us to see light-years away and to better understand the universe. We continue our legacy of advanced space research with the Chandra X-ray Observatory, the Fermi Gamma-ray Space Telescope and the James Webb Space Telescope.

Earth Science

Earth scientists at Marshall use satellites and other advanced technologies to collect data and conduct research on our global climate system. The information gathered is used for improving weather predictions, urban planning and natural resource and environmental management.



Weather Research and Prediction

- Marshall's atmospheric scientists are developing sophisticated instruments and technologies to examine the Earth's most intense storms. For example, the **Hurricane Imaging RADiometer (HIRAD)** maps wind and rainfall to determine the strength and structure of hurricanes. This information improves forecasts and helps minimize property damage and loss of life.
- Marshall pioneers improvements in weather prediction and support for disaster response. Our **Short-term Prediction Research and Transition (SPoRT)** Center team "translates" high-resolution NASA scientific data for use by National Weather Service regional forecasters and weather data models. These tools improve the prediction of severe weather and other weather hazards, and assist end users in applying NASA imagery and products in their response to severe weather events.

Environmental Monitoring

- The **SERVIR** program provides satellite-based Earth observation data and science applications to help developing nations in Eastern and Southern Africa, the Himalayas, Lower Mekong and Central America improve their environmental decision making. The SERVIR system provides this critical information to help countries assess damage, respond to disasters and environmental threats and manage natural resources.
- Marshall also partners with public and private organizations to provide a system called Partnering Earth Observations for People Living Environmentally-Arctic Collaborative Environment, or **PEOPLE-ACE**. This system provides environmental information about the changing Arctic climate and environment to enable local, regional and international responses.
- In addition, Marshall's applied scientists provide satellite data and sophisticated modeling to the Centers for Disease Control and Prevention (CDC) and public health officials. This information helps officials make informed decisions regarding public health concerns such as the impacts of infectious diseases and the effects of urban growth on climate and air quality.
- Our research is also applied to meet societal needs in such areas as agriculture and coastal environments.

Learn more

www.nasa.gov/servir

Earth Right Now: Your Planet is Changing. We're on it.
#EarthRightNow



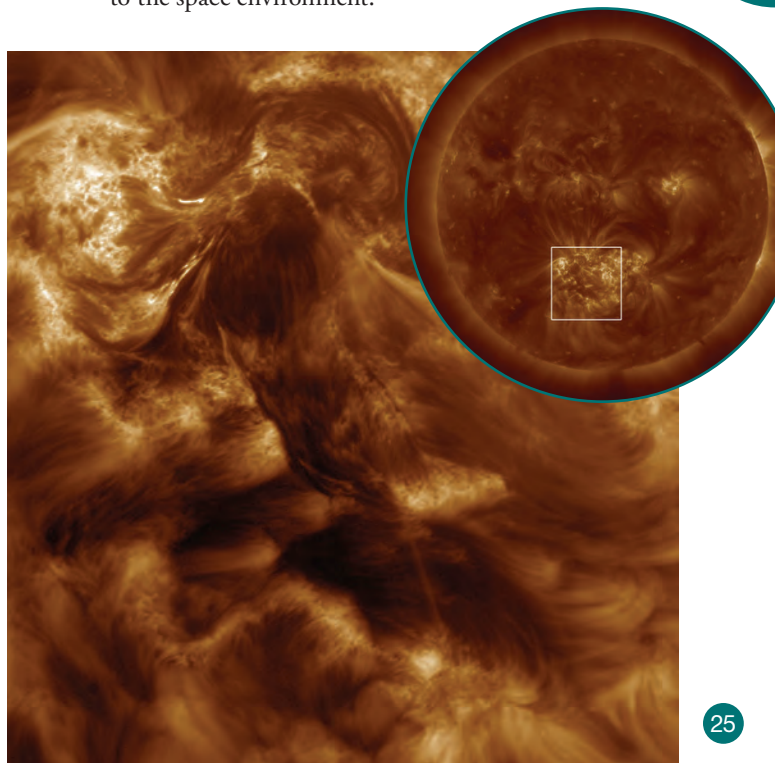
Heliophysics and Planetary Science

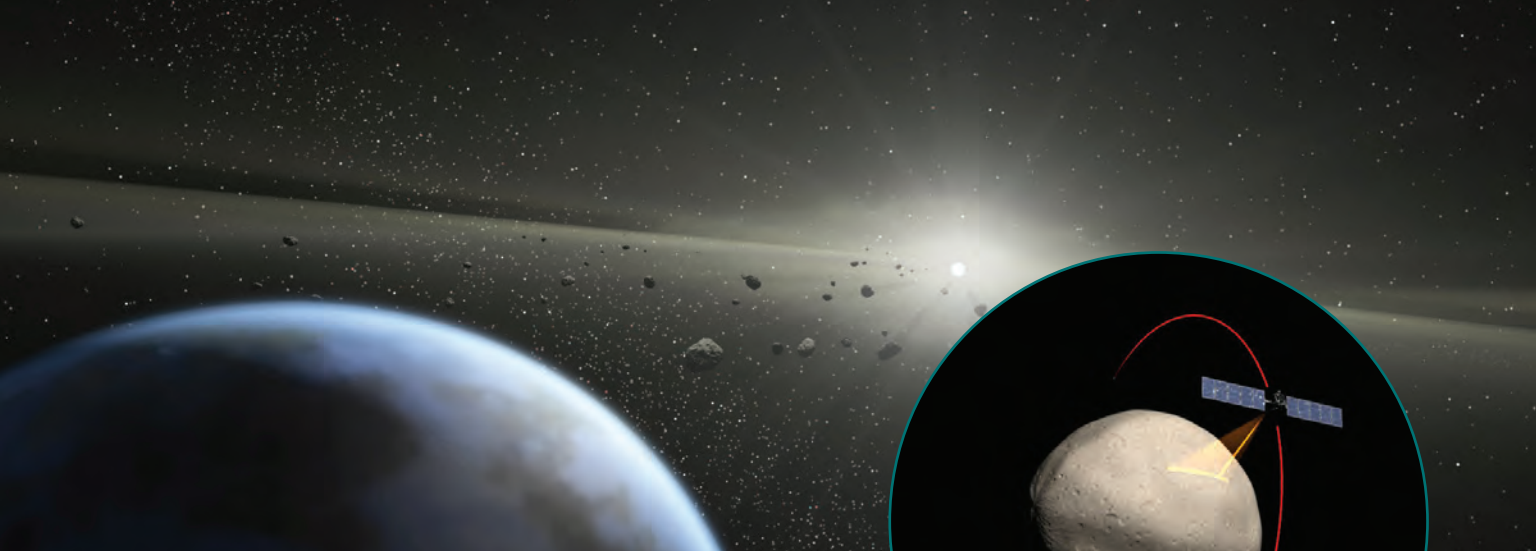
The Heliophysics and Planetary Science group at Marshall studies the sun, how it works and changes, and the impact of solar emissions on the space environment and the environment around Earth. In addition, Marshall planetary scientists are learning about what makes up the solar system, its origin and evolution, and the potential for life in places other than Earth. Using data from orbiting satellites and unique laboratory facilities, Marshall scientists are on the cutting edge of research.

- **Hinode** is a collaboration between NASA, Japan's National Astronomical Observatory, and the space agencies of Japan, the United Kingdom, Norway, and Europe. Instruments on the Hinode spacecraft look at the Sun in visible, Extreme UltraViolet, and X-ray wavelengths of light at high resolution. These data help scientists understand magnetic activity that can create flares and coronal mass ejections. Predicting solar flares and coronal mass ejections that release enormous amounts of energy is critical for protecting communications systems and power grids, orbiting satellites, and astronauts.
- **SWEAP**, Solar Wind Electrons Alphas and Protons, is an instrument being developed for Solar Probe Plus, which, at its closest, will orbit 3.7 million miles from the solar surface, closer than any previous spacecraft, where temperatures are 2,600 degrees Fahrenheit. The purpose of SWEAP is to learn more about the structure and dynamics of the sun's magnetic field and solar wind. SWEAP is a collaboration between NASA's Marshall and Goddard centers, the Smithsonian Astrophysics Observatory (SAO), and the University of Michigan.
- **Hi-C**, or High-resolution Coronal Imager, is the first imager to have a resolution close to the scale of solar coronal structures, structures that are critical to understanding the role of magnetic fields in solar eruptions. A re-flight of the instrument is planned for 2016. Collaborators include SAO, Lockheed Martin Solar and Astrophysics Laboratory, and Southwest Research Institute.
- **CLASP**, the Chromospheric Lyman-Alpha Spectro-Polarimeter, results from a collaboration between the University of Alabama in Huntsville, the National Astronomical Observatory of Japan, the Japan Aerospace

Exploration Agency, and Marshall. Through new technology, CLASP will be the first to measure the Hanle effect in the Sun's chromosphere. CLASP advances technology from the previous Solar Ultraviolet Magnetograph Investigation (SUMI).

- **MaGIXS**, the Marshall Grazing Incidence X-ray Spectrometer, uses a novel optics design to measure the solar spectrum in the range of 6-24 Angstroms with high spatial and spectral resolution, for the first time. These observations will test nanoflare heating in solar active regions and will provide element abundances to compare with stellar abundances. MaGIXS, an instrument in NASA's sounding rocket program, is scheduled for flight in fall, 2018.
- **KaRLE**, or the Potassium (an element signified by "K")-Argon Laser Experiment, is an instrument being developed at MSFC that will determine the age of rocks in situ on the surfaces of the Moon, Mars, and other planetary bodies. With context measurements, a KaRLE-enhanced rover or lander will interpret rock ages and when those rocks were affected by geologic events, e.g., lava flows, fluid alteration, and exposure to the space environment.

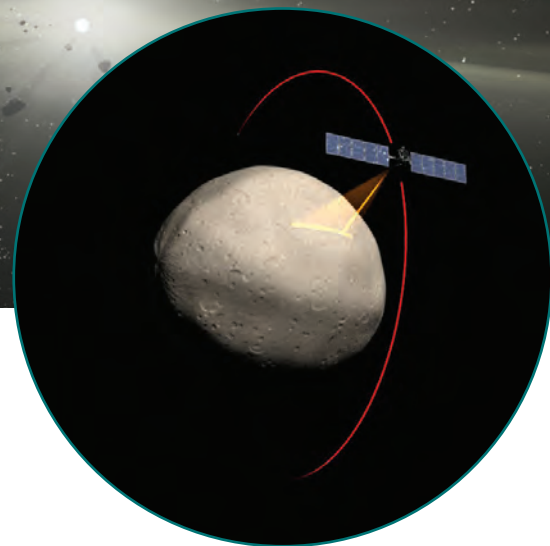




Planetary Science

Marshall manages the Planetary Missions Program Office, which includes the Discovery, New Frontiers and Solar System Exploration Programs. These successful planetary science programs provide mission opportunities that complement NASA's larger planetary exploration goals. Missions include fly-bys, orbiters, landers and sample returns. They probe the nooks and crannies of our solar system, unveiling never-before-seen worlds and entralling us with unprecedented close-up views of those we have seen only at a distance.

These robotic missions help engineers and scientists better understand the solar system's environmental conditions and available resources.



MISSION

Solar System and Beyond

NASA: We're Out There.
#NASABeyond

Learn more

Discovery Program
<http://discovery.nasa.gov>

New Frontiers Program
<http://newfrontiers.nasa.gov/>

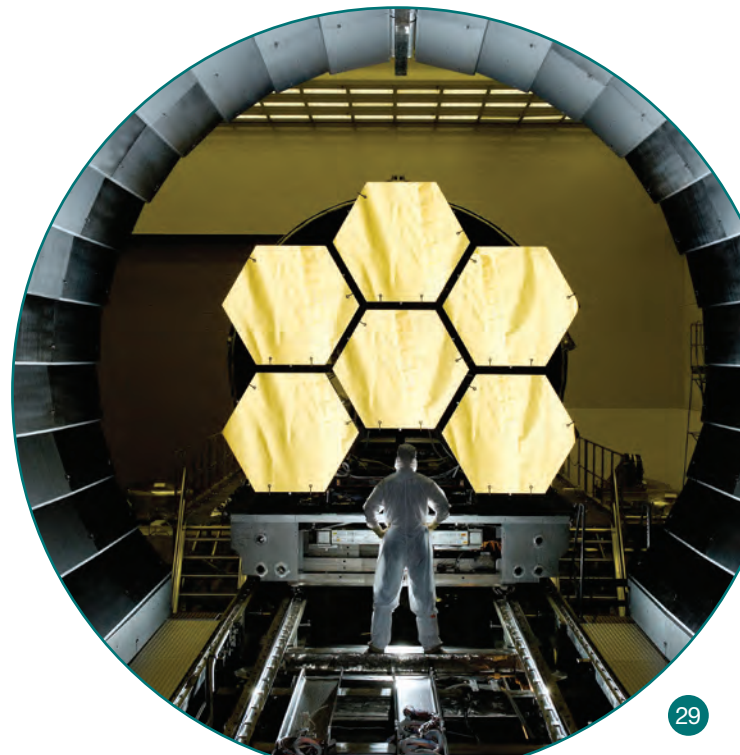


- The **Fermi Gamma-ray Space Telescope** is making pioneering observations of gamma-ray bursts (GRBs), the highest detectable form of electromagnetic radiation, at higher energies than ever before observed from space. In GRBs, we may be seeing the first generation of stars, from the earliest galaxies created after the Big Bang. Not only do GRBs help scientists learn about our universe's history; they also help explain its physics. Marshall developed the Gamma-ray Burst Monitor (GBM), an instrument on board Fermi, which recently captured the largest GRB on record. Together, the Fermi Large Area Telescope and GBM detect and analyze gamma ray bursts with unprecedented precision and coverage.
- The **James Webb Space Telescope (JWST)** is an infrared observatory that can look back in time to find the first stars and galaxies that formed in the universe. Marshall teams used our world-class X-ray and Cryogenic Facility to conduct cryogenic optical testing of the telescope's primary mirror segments. The telescope is targeted to launch in 2018.

Exploring Our Universe

To explore the universe and its infinite wonders, NASA-created space-borne technologies and instruments “see” in different electromagnetic wavelengths such as visible light, gamma rays, X-rays and infrared. Marshall scientists design, develop and test these sophisticated techniques and instruments in the center's specialized facilities.

- Marshall provides scientific expertise and management for the **Chandra X-ray Observatory**, including past development and construction as well as current operations. The universe is a place of sudden and chaotic violence, teeming with supernova explosions, million-degree clouds of intergalactic gas and seething disks of torn-up matter swirling around black holes. Chandra, with its unique ability to see this crucial hot world that holds the key to many scientific mysteries, is helping scientists understand the evolution and structure of the universe.



Keys to the Future

*Solving the unique challenges
of space exploration*

Marshall is building partnerships and developing revolutionary technologies to solve the unique challenges of space exploration.

Our innovative engineers, technologists and scientists leverage proven capabilities in propulsion, space transportation, space systems and scientific research to partner with industry, academia and other government agencies. These partnerships generate solutions for future space adventures—solutions that, in turn, benefit us here on Earth.

Shock Absorbers Save Structures and Lives during Earthquakes

NASA technology developed to pull back the swing arms connecting cords and tubes from a service tower to a rocket immediately before launch has been modified to fortify structures in earthquake-prone areas such as San Francisco and Tokyo. Not one of the more than 550 buildings outfitted with the dampers created by Taylor Devices has sustained even minor earthquake damage.



Technology Development

Marshall technology breakthroughs range from new developments in space transportation and propulsion to key advancements in space systems and science research.

Marshall is exploring the design of landers and human habitats as a proving ground for Mars exploration. We are utilizing our capabilities for advanced manufacturing applications to move forward in-space manufacturing and faster, affordable techniques for propulsion systems. And we're using state-of-the-art facilities to analyze space weather; build sophisticated new sensors and measurement systems; and conduct testing for high-profile NASA missions.

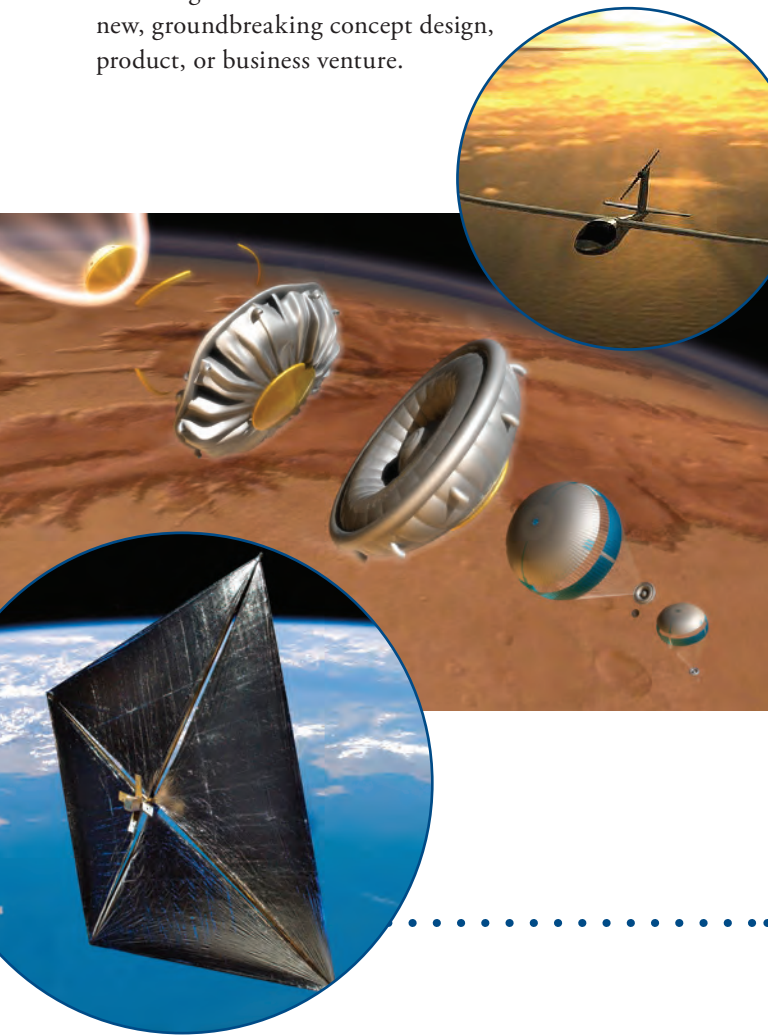
On behalf of NASA's Space Technology Program, Marshall hosts two technology program offices: NASA's Centennial Challenges and the Technology Demonstration Missions program.

Technology

Technology Drives Exploration.
#321TechOff

NASA's Centennial Challenges

Centennial Challenges are technology prize competitions created to inspire innovation and encourage the entrepreneurial spirit. The program challenges enterprising individuals, small businesses and student groups to come up with innovative solutions for technical problems of interest to NASA and the nation. Projects range from sample return robots to flight-qualified, small satellites capable of advanced operations to Mars ascent vehicles. These solutions can have a significant impact on the evolution of existing technologies such as the formation of a new, groundbreaking concept design, product, or business venture.



Technology Demonstrations

NASA's Technology Demonstration Missions program, managed by Marshall, bridges the gap between ground demonstration tests and final flight-testing in space. This program reduces the developmental risk for future missions and provides the final infusion of cost-effective, revolutionary new technologies into robust NASA, government and commercial space programs.

The TDM program focuses on crosscutting technologies that meet the needs of NASA and industry by enabling new missions or greatly enhancing existing ones. Chosen technologies are thoroughly ground-tested and readied for flight testing. These technologies will enable future NASA missions to pursue bolder goals; make human missions safer and more rewarding; and enable new expansion of space industry in the government and U.S. commercial sector.

For example, Marshall is working on a project that explores the use of composite materials in the design, construction and testing of liquid hydrogen tank skirts at the same scale that could be used for SLS. The goal is to explore how these Advanced Manufacturing techniques could reduce the overall mass of a spacecraft.

Collaborative Partnerships

Marshall is building on a legacy of successful, mutually beneficial partnerships to lead NASA and the nation into a rewarding future in space.

Marshall's Partnerships Office is the vehicle for this collaboration. The office pursues new and innovative approaches to pair the center's capabilities with external customer needs and to pair external partner expertise with center needs. The Partnerships Office leverages Marshall's unique capabilities and experienced workforce to foster productive collaborations across industry, academia, government and international organizations.

Our **Small Business Innovation Research Program** and **Small Business Technology Transfer Program** have contributed to technologies that make clean drinking water available throughout the world, alleviate chronic pain for soldiers and civilians, and deliver artificial intelligence based technology to improve tutoring programs.

Technology transfer promotes commercial activity, encourages economic growth and stimulates innovation in business and commerce.



Photo Credit: Water Security Corporation

Made In Space



Spaceflight crews have always had to carry everything they might need with them or wait weeks or months for a cargo resupply mission to bring a replacement for a broken or lost part or tool.

Now, thanks to the Small Business Innovation Research (SBIR) program, Made In Space and Marshall have begun to bridge the gap in the supply chain between Earth and the International Space Station with a customized 3D printer that can perform in-space manufacturing of tools or parts. Files can be loaded onto the machine before launch or uploaded to the printer from Earth while it is in orbit.

The Made In Space printer was installed in November 2014 and has printed more than 20 items, including a wrench that was the first tool built in space. These parts were returned to Earth in February 2015 where they are being studied in comparison to a control group of identical parts made on the same printer before it was delivered to the ISS.

In-space manufacturing is vital for long-duration missions and sustaining human exploration of other planets where there is extremely limited ability to resupply Earth-based products.

Technology Transfer

To better detect aluminum compounds, Marshall partnered with KeyMaster Inc. (later acquired by Wisconsin-based Bruker AXS, Inc.) to develop a vacuum pump system that could be attached to X-ray fluorescence (XFR) scanners. With the resulting technology, hundreds of museums now use the scanners to authenticate artifacts and works of art.



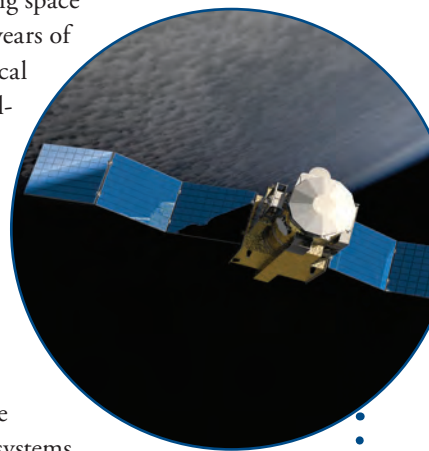
BioServe Space Technologies, a non-profit NASA-sponsored research partnership center, developed a leaf sensor that can monitor plants using electrical pulses, allowing anyone from astronauts to farmers to measure plant water levels. Berthoud, Colorado-based AgriHouse Brands Ltd. has commercialized the technology, which allows “thirsty” plants to send text messages asking for more water.



spinoff.nasa.gov

Capabilities

Equipped with exceptional experience, critical skills and unique facilities, Marshall teams continue to lead some of America’s most exciting space endeavors. Through 50 years of scientific and technological excellence, we have developed a broad portfolio of capabilities.



Core capabilities and services:

- Integrated end-to-end capability to develop safe, affordable, reliable and robust propulsion systems.
- Integrated end-to-end capability to develop and sustain transportation systems.
- Design, develop, analyze and test structures, mechanisms, thermal, environmental, avionics, robotics, power, software and life support systems needed for space activities.
- Develop, test and manage scientific instruments, experiments and spacecraft that gather vital information about Earth and space.

As NASA works with American companies to open a new era of access to space, Marshall seeks innovative and transformative fuels that are less harmful to our environment.

Artist's image of a satellite in orbit. Satellites run off a highly toxic fuel called hydrazine. Marshall is seeking green propellant alternatives to the highly toxic fuel. (NASA)



Propulsion

Marshall researches, develops and matures propulsion technologies for space transportation and science missions. We contribute engineering expertise for all transportation phases, including boost, upper stage and in-space applications.

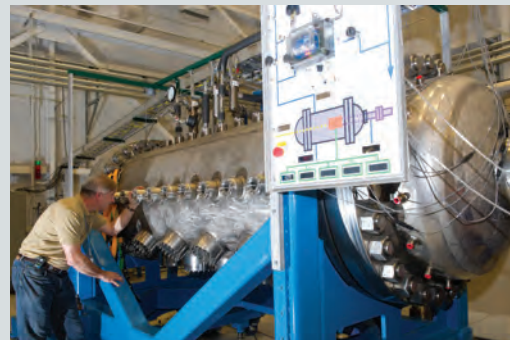
With these capabilities we develop and test

- Propulsion systems, including chemical, electric, nuclear and propellant-free systems such as solar sails.
- Engines and solid rocket motors, from micro-thrusters to systems producing millions of pounds of force.
- Liquid and solid state propulsion systems.
- Propulsion component design and development.
- Pump-fed methane propulsion for landers and in-space transit.



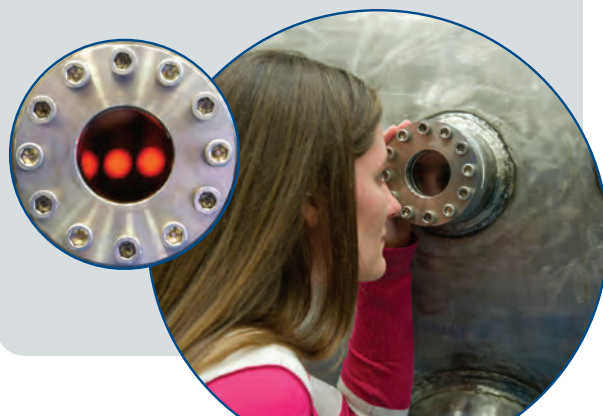
Key Marshall Propulsion Capabilities

- Materials diagnostics, nondestructive evaluation and failure analysis
- Materials technology and development
- Propulsion fluid dynamics modeling and testing
- Propulsion research and technology
- Propulsion testing
- Thermal systems analysis and design



A nuclear thermal rocket could enable reliable delivery of high-mass automated payloads into the deep solar system, or help high-velocity human-rated vehicles speed to and from Mars in half the time required by today's rockets.

The Nuclear Thermal Rocket Element Environmental Simulator (NTREES) is used to study highly promising nuclear fuels. The facility uses non-nuclear heating instead of nuclear fission, so fuel does not become radioactive. NTREES research is driven by one critical goal: enabling a human mission to Mars.





Systems Integration Laboratory where software and hardware come together for the avionics system.

Space Transportation/Launch Vehicles

Marshall know-how is manifest in every stage of spacecraft and launch vehicle development. Expert teams at Marshall develop, test and evaluate materials, processes, designs and systems as well as full-up vehicles like the nation's new Space Launch System. Our comprehensive approach ensures safety, quality and cost-effectiveness.

With our space transportation capabilities we perform

- System design and analysis of structural, avionics and flight mechanics systems.
- End-to-end systems engineering to integrate spacecraft and vehicles with ground processing and launching facilities.
- Vehicle technical design and verification, from concept through post-flight assessments.
- Sustaining engineering support to space transportation systems.



Marshall engineers use the Collaborative Engineering Design and Analysis Room (CEDAR) to study design and simulations of exploration projects.

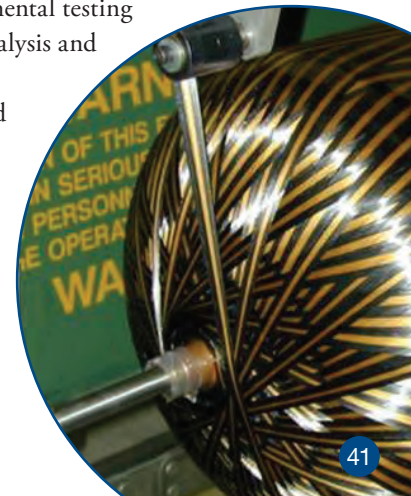


Vertical Assembly Center

The Vertical Assembly Center is the largest spacecraft welding tool in the world. The 170-foot-tall, 78-foot-wide facility completes a world-class welding toolkit used to build the core stage of SLS. Part of a family of state-of-the-art tools designed to weld the core stage of SLS, the VAC joins domes, rings and barrels to complete the tanks or dry structure assemblies.

Key Marshall Expertise

- Advanced concepts and architectures
- Advanced manufacturing
- Avionics and electrical systems
- Damage tolerance and fracture mechanics
- Large-scale manufacturing
- Space environments and effects
- Structural and environmental testing
- Systems engineering, analysis and integration
- Vehicle development and integration



Space Systems

Marshall supports the agency in developing large space structures and the space systems that support them. Our contributions have included the Lunar Roving Vehicle, Skylab, Spacelab, and International Space Station modules. Many of Marshall's space systems are showcased in the ISS:

- Logistics modules and connecting “nodes”
- Materials Science Research Rack (MSRR) experiment integration
- Environmental Control and Life Support System (ECLSS)
- Our Payload Operations Center, the space station's primary science command post
- Microgravity Science Glovebox

With a range of space systems capabilities, Marshall is laying the foundation for a new era of space exploration.

Key Marshall Expertise

- Avionics and electrical systems
- ECLSS design and development
- Guidance, navigation and control
- Material technology and development
- Mission operations
- Optical systems design, development, fabrication and testing
- Payload systems technology, development and integration
- Small spacecraft design, development and testing
- Space environments and effects



The Near Earth Asteroid (NEA) Scout is a Marshall-managed design and development project of a 6U CubeSat scheduled to fly on the first launch of the Space Launch System (SLS) as a secondary payload. NEA Scout is a partnership with the Jet Propulsion Laboratory. Marshall is performing the design, development and testing of an innovative solar sail propulsion system.



Marshall solar physicists and engineers designed and built the Solar Ultraviolet Magnetograph Investigation, or SUMI, to determine the strength and direction of magnetic fields in a region of the sun where the magnetic field has never been measured.

Science

Marshall develops, tests and manages scientific instruments, experiments and spacecraft that gather vital information about Earth and space.

Our scientists

- Develop tools to provide better monitoring and prediction of Earth's weather, climate and other environmental impacts.
- Study and predict the sun's dynamics to improve forecasts of the solar eruptions and space weather that can affect humans.
- Study planetary atmospheres, interiors and histories.
- Seek to understand dark matter and dark energy through X-ray astronomy investigations and studies of gamma ray bursts and cosmic rays.

Key Marshall Scientific Expertise

- Advanced concepts
- Earth science research and applications, heliophysics, high-energy astrophysics and planetary science research
- Guidance, navigation and control
- Mission operations
- Optical systems technology, development and integration
- Payload systems technology, development and integration
- Space environments and effects
- Structural and environmental testing
- Thermal systems design

Visiting Marshall

Because access to Redstone Arsenal is restricted, visitors to Marshall must have prior approval to visit and must obtain a badge at the Redstone Arsenal Visitor's Center at Gate 9 on Research Park Boulevard/Rideout Road South or at Gate 1 on Martin Road.

The Official Visitor Information Center for Marshall is located at the U.S. Space & Rocket Center. Interactive exhibits and unique historic artifacts demonstrate Marshall's critical role in supporting NASA's missions.

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